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*CONCEPT FORMATION, LEARNING PROCESSES, CONCEPT TEACHING, FUNDAMENTAL CONCEPTS, *TAXONOMY, *PROBLEM SOLVING, TEACHING TECHNIQUES, *BIBLIOGRAPHY, PUBLICATIONS, PERIODICALS, *RESEARCH AND DEVELOPMENT CENTERS, MADISON, WISCONSIN

THIS TECHNICAL REPORT PRESENTS A DEFINITION OF CONCEPT, A TAXONOMY OF VARIABLES SIGNIFICANT IN CONCEPT LEARNING, AND A BIBLIOGRAPHY OF ARTICLES DEALING WITH CONCEPT LEARNING AND PROBLEM SOLVING. A TOTAL OF 46 PERIODICALS SELECTED FOR SCANNING WERE THOSE KNOWN TO CONTAIN ARTICLES CONCERNED WITH PROBLEM SOLVING AND CONCEPT FORMATION. THE TEXT OF THESE ARTICLES IN ALL ISSUES FROM 1950 TO 1964 WAS EXAMINED TO DETERMINE WHETHER THE ARTICLE MET ALL OF THE ESTABLISHED CRITERIA FOR INCLUSION IN THE BIBLIOGRAPHY. THE BIBLIOGRAPHY WAS PRESENTED IN THREE SECTIONS--(1) CONCEPT-LEARNING ARTICLES, ALPHABETICALLY BY AUTHOR, (2) PROBLEM-SOLVING ARTICLES, ALPHABETICALLY BY AUTHOR, AND (3) ALL ARTICLES BY JOURNAL AND YEAR. RESPONSES TO THE DEFINITION, TAXONOMY, AND LIST OF ARTICLES WERE INVITED. (JC)

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Technical Report No. 1

CONCEPT LEARNING AND PROBLEM SOLVING

A BIBLIOGRAPHY, 1950-1964

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LIST OF JOURNALS SCANNED

Acta Psychologica
American Journal of Mental Deficiency
American Journal of Psychology
American Psychologist
American Sociological Review
Annual Review of Psychology
Behavioral Science
British Journal of Educational Psychology
British Journal of Psychology
Canadian Journal of Psychology
Child Development
Childhood Education
Education
Educational and Psychological Measurement
Elementary School Journal
Genetic Psychology Monographs
Harvard Educational Review
Journal of Abnormal and Social Psychology
Journal of Applied Psychology
Journal of Clinical Psychology
Journal of Comparative and Physiological Psychology
Journal of Consulting Psychology[1]
Journal of Educational Psychology
Journal of Educational Research
Journal of Experimental Child Psychology
Journal of Experimental Education
Journal of Experimental Psychology
Journal of General Psychology
Journal of Genetic Psychology
Journal of Nervous and Mental Disease
Journal of Personality[2]
Journal of Psychology
Journal of Research in Science Teaching
Journal of Social Psychology
Journal of Verbal Learning and Verbal Behavior
Perceptual and Motor Skills
Psychological Bulletin
Psychological Monographs: General and Applied
Psychological Records
Psychological Reports
Psychological Review
Psychonomic Science
Quarterly Journal of Experimental Psychology
Review of Educational Research
Scandinavian Journal of Psychology
Science Education

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[1] Vols. 22-24 not available

[2] Vol. 29 not available

INTRODUCTION

The main purpose of this technical report is to present a definition of concept, a taxonomy of variables significant in concept learning, and a bibliography of articles dealing with concept learning and problem solving. We hope that other researchers in the area of concept learning and problem solving will inform us concerning the usefulness and completeness of this material.

One primary interest of the Center is to extend knowledge about the learning and teaching of concepts. One step in achieving this goal is to catalog and abstract the literature which is concerned with concept learning and problem solving. This cataloging and abstracting began immediately after the Center was established in September, 1964.

As the task of cataloging and abstracting progressed[1] it became apparent that a definition of concept was needed in order to specify more exactly what is to be included in this domain. No definition of concept appeared adequate as a basis for organizing present knowledge and starting new experiments. An attempt was made, therefore, to define concept in terms of attributes. The definition of concept according to attributes, which is still in a formative stage, may be used by the psychological experimenter or the educational researcher to gain perspective for his own definition. Our definition according to attributes may also be helpful in delimiting a highly significant field of investigation which is now characterized by semantic confusion. The following section of this report is devoted to the analysis of concepts in this way.

Concurrently with the preceding activity, the development of a taxonomy of variables in concept learning was begun. The identification of these variables is essential as a framework for conducting long-term, programmatic research on concept learning and for organizing what is already known. Only as the relevant variables are identified can experiments be conducted to find functional relationships among the variables.

In setting up the taxonomy of variables we have drawn from our own experimentation, the research reports of others, and the attempts of others to classify variables in concept identification. In the Annual Review of Psychology of 1961, Tracy S. Kendler reviewed research under four main headings: stimulus factors, motivation and reward factors, response factors, and genetic factors. In 1961, this system of factors or variables appeared reasonably adequate. However, it will be noted in the subsequent section that we have departed considerably from this 1961 arrangement.

Since any taxonomy is subject to revision as experimentation progresses, we continuously check our taxonomy of variables against the review of research. This enables us to determine the extent to which the taxonomy is sufficiently specific and complete. We are continuously adding to the list of variables and reorganizing the taxonomy. The taxonomy may help the researcher determine where his research fits into a larger pattern.

In our search of the literature, articles pertaining to problem solving and concept formation were first identified through examining Psychological Abstracts and Education Index. Because spot checks of these extensive lists indicated that some relevant articles were not included, a systematic and comprehensive search of the journals was deemed necessary.

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[1] At this time approximately 80% of the articles dealing with concepts are abstracted, and we are relating these articles to the taxonomy. Decisions are yet to be made about producing other technical publications based on these abstracts.

The 46 periodicals selected for scanning (see page v) were those known to contain articles concerned with problem solving or concept formation. The text of each article in all issues from 1950 through 1964 was examined to determine whether the article met all of the established criteria. For inclusion in the bibliography, the article was to (1) include the term(s) "concept," "concept formation," "concept identification," "concept attainment," "conceptual learning," or "problem solving" in either (a) the title, (b) a subheading, (c) an abstract of the article, or (d) the summary or conclusion; (2) be a controlled experiment or a theoretical article discussing and integrating empirical research; (3) use human subjects only.

One difficulty encountered in working with any system of established criteria is that strict adherence to definite standards presents problems of judgment. Much time was spent considering the final acceptance of the entries which appear here.

The list of articles on concept learning and problem solving which have appeared in the specified journals during the period 1950-1964 should be helpful to anyone who wishes to estimate the scope of the entire field. Also, since this list is more easily used than are most library reference works, including Psychological Abstracts, it is an efficient guide for the experimenter's library search.

The bibliography is presented in three sections: concept-learning articles alphabetically by author; problem-solving articles alphabetically by author; and all articles by journal by year. Articles in journals having more than one volume per year are arranged by volume within year. In the last section the letters C and P identify the classification of each article.

Since we are interested in securing feedback from users of this report, we invite responses to the following:

A. Definition of concept.
   1. What are the possible revisions in our definition of a concept in terms of its attributes?
   2. Can individuals who agree upon the attributes identify concepts reliably in subject matter fields such as mathematics, biology, history, and English?

B. Taxonomy of variables.
   1. What specific variables should be added to or deleted from the list?
   2. Are the main variables the most critical and powerful in concept learning?
   3. Can some other system be devised which will indicate more clearly relationships among the sets of variables?

C. List of articles.
   1. In view of the working criteria, what additions or omissions of articles can be made?
   2. What advantages are there in providing a cross-reference of articles according to journals?

The preceding questions indicate the complexities of the problem which arise when one attempts to determine what is known in a field such as concept learning and to organize it into a meaningful pattern. (It suggests also the possibility of cooperative efforts. In this connection, a project of the U. S. Office of Education is to develop a thesaurus of educational terminology. Also, a national system of information storage and retrieval is being developed by the U. S. Office of Education.) At present, we are unaware that an attempt such as this has been made to list the variables and to identify terminology by which knowledge about concept learning may be classified. Anyone who wishes to cooperate with the Research and Development Center in this effort is cordially invited to do so.

DEFINITION OF A CONCEPT

In the psychological and educational literature one finds such definitions of concept as:

"The concept deals with the meaning an individual attaches to a word or other symbol, rather than with the mere fact that any given symbol is associated with any given object." (Woodruff, A. D. The psychology of teaching. New York: Longmans, Green, 1951, 285.)

"Concept is . . . a common response to dissimilar stimuli." (Kendler, Tracy S. Concept formation. In Annual review of psychology. Stanford: Stanford University Press, 1961, 447.)

"A concept may be regarded as a verbal habit-family formed usually on the basis of a class of stimulus objects having identical elements." (Staats, A. W. Verbal habit-families, concepts, and the operant conditioning of word classes. Psychol. Rev., 1961, 68, 195.)

A concept is the recognition of "a group of situations which have a resemblance or common element. We usually give a name or label to the group." (Cronbach, L. J. Educational psychology. New York: Harcourt, 1954, 281.)

"Concepts are learnings that permeate thinking." (Russell, D. H. Concepts. In C. W. Harris (Ed.), Encyclopedia of educational research. New York: MacMillan, 1960, 323.)

These excerpts of definitions indicate why one may become confused when first attempting to delimit what is meant by concept. Let us introduce our definition by re-emphasizing that the term concept means many different things to many different individuals. We recognize the complex nature of concepts and have attempted to define a concept in terms of its attributes. (Some may prefer the term dimensions.) Anything that is a concept has the following attributes:

I. Psychological meaningfulness
II. Intrinsic, functional, or formal properties
III. Abstractness
IV. Inclusiveness
V. Generality
VI. Structure
VII. Function

I. PSYCHOLOGICAL MEANINGFULNESS

An individual's concept of anything is a product of his thought. It is a construct somewhat unique to him. Thus, the concept of animal is very different for a child of 5 from what it is later at age 10 or again at age 25 when he completes his Ph. D. in zoology. From the standpoint of psychological meaningfulness, a concept is the meaningful associations that the individual has formed about objects or events that enable him to categorize these objects or events as belonging to the same class and to associate relevant observable and unobservable attributes to them. Psychologically, a concept that the individual possesses is a network of inferences or meaningful associations rather than merely the responses that are common to otherwise dissimilar objects or events.

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[1] Based on material in Klausmeier, H. J., & Goodwin, W. L. Learning and human abilities. (2nd ed.) New York: Harper and Row, in press. Chapter 7.

Here we may distinguish between concepts and pre-concepts. A child may observe objects and may be able to classify them properly without being able to state the word which represents the concept. For example, a child puts triangular, circular, and square objects into proper groups but does not say the words triangle, circle or square. The child has a pre-concept of circle, square, and triangle. The distinction between pre-concept and concept is one of preference. However, much confusion can probably be avoided by specifying that the individual must be able to use the vocabulary appropriate for the concept.

II. INTRINSIC, FUNCTIONAL, AND FORMAL PROPERTIES

Many properties of objects can be experienced directly through the sensory organs; others can be experienced with instruments of various types. Observable properties which allow otherwise dissimilar objects or events to be put into one category might be called intrinsic properties. For example, all animals having backbones belong to the sub-phylum vertebrata. Similarly, animals that are warm-blooded, have mammary glands, and have hair are mammals. A liquid possessing certain properties is called water, regardless of where it is found. In the physical world these intrinsic properties of objects provide one basis for categorizing and relating. These are the so-called common elements or qualities, abstracted from the exemplars, that comprise the concept.

Man invents many means of classifying things as similar. For example, strawberries, bread, and ice cream are all called food. Although they do not have perceptually common properties, they serve a similar function. (The intrinsic properties of each, of course, can be specified.) A nail, a metal clamp, and a piece of card can be used to hold two pieces of wood together. Basing the classification of objects on the function or use of the objects is widespread.

Man has, however, invented systems (having no intrinsic properties) such as the number system and the alphabet. Both the Arabic and the binary system have properties, but these are the products of man's inventiveness. Yet the concepts in the Arabic number system do have formal properties that are agreed upon by mathematicians. As a matter of fact, there is probably more agreement concerning the properties of concepts in mathematics than there is in botany or zoology. These man-made formal properties are as useable as intrinsic properties in determining class inclusion.

At this point, it is apparent that there is some overlap between the attribute of psychological meaningfulness and the attribute of intrinsic, functional, or formal properties. The primary distinction is this. The latter can be defined by individuals who know most about the concept. We have a clearly defined concept to the extent that the men who know most about something can agree on its properties. Others who know very little about the specific properties do have a concept, but it is incomplete and inadequate in terms of expert knowledge. The properties, then, are objective while meaningfulness is subjective.

In connection with the intrinsic, functional, and formal properties of concepts, we can observe that nouns in the English language represent concepts. In mathematics, for example, nouns such as one, two, number, fraction, addition, and multiplication represent concepts. Many adjectives also embody concepts. In general the adjectives related to the various sensory modalities embody concepts. Green, yellow, noisy, musical, bitter, sweet, hot, cold, rough, and smooth represent adjectival concepts. Concepts are also embodied in other parts of speech including some verbs, prepositions, and pronouns.

III. ABSTRACTNESS

Concepts range on a continuum from concrete to abstract. On the more concrete end are the concepts for which examples are readily available to the senses. Towards the abstract are concepts represented in purely verbal terms, completely removed from any actual definite referents. For example, one has a concept of plant based on many experiences with many individual plants, whereas, the concept eternity has no similar concrete referents. Concepts in the plant and animal kingdom generally have exemplars; that is, one can find examples of the concept. In mathematics one can create representations of a concept such as point but cannot provide an observable exemplar of it.

IV. INCLUSIVENESS

Concepts range in inclusiveness from one member or exemplar to an unspecified number of exemplars. The identity concept includes one exemplar only. Each person is an identity concept because he is unique; a person, though changing in some characteristics with age, is still recognized as the same individual. Though the exemplars differ, they are classed as the same thing. On the other hand, there are countless grains of sand, blades of grass, drops of water.

V. GENERALITY

The most specific concepts include exemplars of one class only; general concepts include exemplars drawn from higher supraordinate classes embodying many subordinate classes. Living things and inanimate objects are two highly general concepts. The concept dog has exemplars of the dog category only, whereas, the concept vertebrata applies to many lower-order categories.

Concepts are arranged hierarchically into conceptual schemes. Within the same conceptual scheme, the more general the concept, the more inclusive it is. However, the most general concept in one hierarchical arrangement may include fewer exemplars than the least general in another hierarchy.

VI. STRUCTURE

The properties of a concept are related to one another in some fashion. This relationship may be designated as the structure of the concept. Bruner, for example, classifies concepts as conjunctive, disjunctive, and relational.[2] Synonyms to conjunctive are joining and connective. A conjunctive concept is one in which all the values of the attributes are present at the same time. For example, a sentence has a subject and a predicate. If either is missing, the group of words is not a sentence. Similarly, some of the attributes of mammal are warm-blooded, having mammary glands, and possessing hair. If any one of these is not present, an animal is not a mammal. Many concepts which constitute classification or categorizing schemes are of the conjunctive type.

Disjunction implies separation, not joining. A disjunctive concept is one in which the attributes are not present in all examplars. For example, a strike in baseball is a type of disjunctive concept because it can occur in a number of different ways, yet each is called a strike. A strike may be a ball thrown in the strike zone and called by the umpire. It may be a foul tip, or it may be a ball swung at but missed. At a more abstract level, Hindus, Moslems, Jews, and Christians are included in the concept religion although they differ markedly in their conceptions of the deity and worship.

Relational concepts, the third type, involve dependencies and are embodied in words such as taller, older, wider, between, and down. For example, a person at age 40 is older than another at 30 but younger than one at 50. Geographic concepts such as south and north are relational. Relational concepts are difficult to acquire, in part because the intrinsic attributes cannot be specified independently. We cannot give the attributes of south and younger except in terms of north and older.

VII. FUNCTION

Concepts serve two main functions in human behavior: as responses to objects and events by which they are classified or categorized, and as mediators between stimulating events and subsequent behavior. Thus far, we have been concerned mainly with specifying attributes of concepts that clarify the response function. Consider the mediation function of concepts.

Assume that one has already developed some concepts. Having concepts enables the individual to deal more effectively with the physical and social world by simplifying it. For example, if a person has the concept book then he treats all objects which fit his concept of book as belonging to the same classification or set. All other objects may be treated as non-books. This simplifies the environment in that one no longer has to treat each book object as a specific new entity. Instead, one deals with entire classes of objects and events. In other words, concepts serve to mediate between stimulating events and subsequent behavior.

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[2] Bruner, J. S., Goodnow, Jacqueline J., & Austin, G. A study of thinking. New York: John Wiley, 1961, pp. 41-45.

Concepts mediate in other ways. Knowing the attribute of a class concept facilitates recognizing other examplars of the same class when they are encountered for the first time. For example, if one knows the attributes of a noun and has specified some examples of nouns he will have little difficulty in properly classifying words in a sentence as noun or not-noun. The mediation aspect of concepts thus enables the individual to learn more efficiently.

Concepts serve as mediators, in another way. Some concepts involve values and thus influence our behavior towards the exemplars of the concept. For example, murderer and thief have at least one attribute involving a value, namely, violation of the laws of society. Our understanding of these concepts affects our behavior, specifically our reactions to those who fit the category. When we know that a murderer is at large, we do not pick up a hitchhiker. These few examples show how concepts mediate the physical and social world, helping to make it less complex, enabling us to learn more efficiently, and affecting our behavior where values are concerned.

OTHER WAYS FOR ORGANIZING CONCEPTS

This definition of concepts in terms of specified attributes is, to the best of our knowledge, a first attempt in this direction. There have been many attempts to organize and classify concepts according to subject matter. For example, one system puts all concepts in five classes according to content — events, processes, and behavior; people; sensory substances; dimensions and spatial and quantitative relationships; and personal feelings within persons. In the recent Roget's Thesaurus, the eight main classes for organizing more discrete information are abstract relations, space, physics, matter, sensations, intellect, volition, and affections. At present we are unable to offer a better classification of concepts according to content. However, a better content classification is urgently needed, especially to identify related concepts and conceptual schemes in school subject matter.

TAXONOMY OF VARIABLES IN CONCEPT LEARNING

I. Stimulus Variables Related to:
  A. Concepts
    1. Number of concepts to be learned per trial or block
    2. Time per concept
    3. Order of difficulty of concepts
    4. Level of concepts in hierarchy
    5. Perceptual obviousness of concepts
    6. Structure of concepts
    7. Meaningfulness of concepts
    8. Affective content of concepts
    9. Novelty of concepts
    10. Similarity of concepts
  B. Dimensions
    1. Number of values per dimension
    2. Discriminability of values
    3. Number of relevant dimensions
    4. Number of irrelevant dimensions
    5. Sense modality by which dimensions are perceived
    6. Relative salience of dimensions
    7. Subjectivity of dimensions
  C. Instances
    1. Time per instance
    2. Order of instances
    3. Physical location of instances
    4. Number of instances presented
    5. Homogeneity of instances
    6. Associative rank of instances
    7. Number of dimensions varied from instance to instance
    8. Ratio of positive to negative instances
    9. Discriminability of positive from negative instances
  D. Presentation of information
    1. Gross method of instance presentation
    2. Material used to portray stimulus information
    3. Stimulus labelability
    4. Availability of previously presented information
    5. Redundancy of information

II. Instruction Variables Related to:
  A. General purpose of instructions
    1. Recall of relevant subordinate abilities
    2. Provide advance organizers
    3. Guide thought process
    4. Incorporate an instructional set
    5. Arouse searching orientation
    6. Provide mediators
  B. Specific information in instructions
    1. Number of examples used
    2. Homogeneity of examples
    3. Amount of explanation of stimulus materials
    4. Amount of explanation of principles
    5. Amount of irrelevant information
    6. Information about type of concept
    7. Information about number of relevant dimensions
    8. Information about performance measure(s)
  C. Presentation
    1. Type of exposition
    2. Type of program
    3. Mode of presentation
    4. Time allotted

III. Response Variables Related to:
  A. Overt responses
    1. Mode of response
    2. Delay of response
    3. Time for response
    4. Activity level of responder
    5. Variance of response dominance
    6. Number of sorting categories
  B. Inferred responses
    1. Use of mediators
    2. Type of mediators
    3. Use of strategies
    4. Type of strategies
    5. Level of awareness
    6. Type of hypotheses formed
    7. Level of cognitive functioning

- C. Assessment of responses
  - 1. Measure of learning and retention
  - 2. Types of errors
  - 3. Transfer tasks

IV. Organismic Characteristics

- A. Cognitive
  - 1. Previous achievement or experience
  - 2. General intellectual ability
  - 3. Specific abilities
  - 4. Cognitive style
- B. Psychomotor
- C. Affective
  - 1. Interests
  - 2. Attitudes
  - 3. Values
  - 4. Emotional state
  - 5. Need states
  - 6. Personality integration
- D. Physical
  - 1. Age
  - 2. Sex
  - 3. Handicaps
- E. Socio-cultural
  - 1. Ethnic group
  - 2. Socio-economic level
  - 3. Occupational group
  - 4. Neighborhood
  - 5. Family setting

V. Conditions of Learning Related to:

- A. Practice
  - 1. Distribution of practice
  - 2. Amount of pretraining
  - 3. Amount of practice in mastering task
  - 4. Amount of overlearning
  - 5. Prompting on practice trials
- B. Feedback
  - 1. Delay of feedback
  - 2. Intensity of feedback
  - 3. Probability of feedback
  - 4. Probability of misinformative feedback
  - 5. Post feedback interval
- C. Experimenter-subject interaction, teacher-pupil interaction
- D. Motivation
  - 1. Peer-group influence
  - 2. Arousal value of task
  - 3. Solubility of task
  - 4. Competition
  - 5. Cooperation
  - 6. Reward and punishment
  - 7. Set to learn
- E. Sequence
  - 1. Interpolated activities
  - 2. Induction-deduction
  - 3. Retroactive-proactive inhibition models

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